Asymmetry of Leaf Plates of Elm Stick under Industrial Zone Conditions

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Abstract

Assessment of the environmental quality of the industrial zones of the Kashkadarya region was carried out using fluctuating asymmetry of the elm leaves of the squat (Ulmus pumila L.). The method used was based on identifying violations of the symmetry of the development of a leaf plate of a tree species under the influence of anthropogenic factors, where the extent of asymmetry reflects the relative strength of impact. Ulmus pumila L. leaf samples were taken at 4 points in the Kashkadarya region at various recreational sites with different anthropogenic loads and remoteness from the main sources of pollution. The leaves of Ulmus pumila L. in the areas surveyed were characterized by the presence of asymmetry to various extents exceeding the relative magnitude of the normal variance. At the same time, in Muborak Gas Processing Plant and Shurtan Gas Processing Plant, the average index of fluctuating asymmetry corresponded to grade IV on the scale of environmental quality assessment, which is characterized as a critical state of the environment.

Keywords: Bioindication, fluctuating asymmetry, elm, green plantings

1. Introduction

Nowadays, the conservation of environmental quality becomes a desirable task during the planning and greening of industrial zones. One of the promising approaches for the complex characterization of environmental quality is the assessment of living organisms for the stability of their development, namely, the level of fluctuating asymmetry of their morphological structure (Dadaeva, 2006). The reaction of living organisms to environmental stress by increasing their asymmetry was reported for plants (Zakharov et al. 2020; Shadrina et al.2020), insects (Ivanković Tatalović et al. 2020) and even mammals (Chirichella et al. 2020).

The use of fluctuating asymmetry assessment has been a good method to evaluate the extent of environmental stress (Chirichella et al. 2020; Shadrina et al.2020; Zakharov et al. 2020; Kozlov et al. 1996). The expression of fluctuating asymmetry can indicate air pollution (Erofeeva and Yakimov, 2020; Wuytack et al. 2020) and the presence of heavy metals (Mabrouk et al. 2020).

Tree species in industrial zones bear protective functions, generate oxygen release phytoncides, air purification, and formation of a specific microclimate. However, tree plantations in industrial zones are affected negatively by air pollution (Zakharov et al.2006). Kashkadarya region is one of the industrial centres of South Uzbekistan where the environment is affected

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negatively by the existing industries: Muborak gas processing plant; Shurtan gazo-chemical complex; Shurtan gas-processing plant. Thus, the study of plant growth and development in industrial zones has increasing importance from year to year.

One of the convenient methods to assess the intensity of industrial charge on the environment is the method of assessment of environment quality using the study of deviation in the stability of the development of trees. The main principle is the assessment of the extent and frequency of deviations of asymmetry in the leaf development of trees under industrial conditions. The method is simple in terms of sample collection, storage and treatment, and it allows a complex assessment of the status of trees (Runova et al. 2013a, b). The diagnostic of atmosphere status using the Use of plants as bio-indicators is based on the high sensitivity of plant communities to the presence of atmospheric pollutants and is an inexpensive research method. Plants respond to the presence of pollution through early morphological changes such as changes in leaf color, the appearance of necrosis, prematurely wilting and defoliation (Gavrilin and Runova, 2012; Sherzhukova et al.2001). Our study aimed to assess the status of industrial zones of South Uzbekistan using the method of varying asymmetry of Ulmus pumila L. leaves.

2. Materials and Methods

The study was conducted on an elm tree, Ulmis pumila L. This species has relatively well-expressed lateral dissymmetry (the right half of the leaf is slightly shorter than the left one), which was a key condition for this study. Besides, the elm tree is widely occurring in industrial woodlot plantations where it reaches from 10 to 20% of tree composition, and it is common in each industrial zone of the Kashkadarya region.

Elm tree leaf samples were collected on 3 different industrial objects (1-Muborak Gas Processing Plant; 2-Shurtan Gaso-Chemical Complex and 3-Shurtan Gas Processing Plant), and 4- Sanitary zone of Karshi City, which is relatively clean and served as control, with 3 replicates. The investigated areas differ by anthropogenic charge and distance from the main sources of pollution. The air concentration of SO2 exceeded the maximum permitted level, while the decreased organic matter was observed in all industrial objects (Table 1). The location of sampling points in Kashkadarya region is shown in Figure 1.

Table 1. Characteristics of sampled sites, Kashkadarya region, 2018

Sampled sites	SO_2 air concentration, mg/m^3	Organic matter, mg/kg	Mean annual air temperature, ^{O}C	Rainfall, mm/year	Vegetation period, days
Site1 (Muborak Gas Processing Plan)	0.054±0.019	0.6-0.8	14.1	155	291
Site 2 (Shurtan Gas-Chemical Complex)	0.046±0.0017	0.8-1.3	15.7	225	303
Site 3 (Shurtan Gas Processing Plant)	0.051±0.011	0.7-1.1	15.7	225	303

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Sampled sites	SO_2 air concentration, mg/m^3	Organic matter, mg/kg	Mean annual air temperature, ^oC	Rainfall, mm/year	Vegetation period, days
Site 4 (Sanitary zone of Karsha City)	0.040±0.0015	0.9-1.6	14.9	240	301
Maximum acceptable concentration (for wood species)	0.03	1.9-2.4	-	-	-

Sample collection was done using the method of assessment of the status of tree species by the indicators of development deviations (Dadayeva, 2006). Leaf sampling was done at the beginning of November 2018 from a few trees within the area of 15 x 15m or along road areas of 30-40 m in length. A total of 50 leaves were taken (10 samples from 5 trees) within each selected area. A total of 600 leaf samples were collected. Medium-sized trees were used only. Leaves were collected from the lower part of the tree crown, at a level of 2m approximately and from well-developed branches. The method of A.D. Dadayeva is based on an assessment of the asymmetric deviation of leaf sheets based on leaf measurements (Dadayeva, 2006). Five measurements were taken on each side of the leaf sheet, left and right (Figure 2). Measurements were done on freshly collected leaf material in the laboratory using a measuring compass, ruler and protractor.

For the calculation of deviations, the method of V.P. Zakharov (2006) was used:

1) For each measured leaf, relative asymmetry was calculated for each character, and the difference between left and right-side measurements was divided by the sum of these measurements: (L – R)/(L+R);

2) The indicator of asymmetry was calculated for each leaf by summing of relative values of asymmetry for each parameter and then dividing by the number of parameters, the integral indicator of the stability of development was calculated and expressed as the mean relative difference between right and left side measurements by a parameter.

3) The indicator of leaf development stability was calculated as the mean relative difference between leaf sides divided by the character, for this, the mean asymmetry of all asymmetric values was calculated.

4) Mean per sampling area was produced.

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Figure 1. Site location of sampling sites for elm tree leaf sampling for Ulmus pumila L. In Kashadarya region: (1 - (Site-1) Muborak Gaz Processing Plant, 2 - (Site-2) Shurtan Gas-Chemical Complex 3 - (Site --3) Shurtan Gas Processing Plant, 4 - (Control) Sanitary zone of Karshi City)

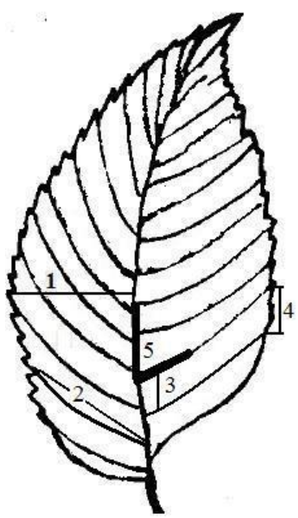

Figure 2. Leaf measurements: 1 –width of half-leaf; 2-length of second vein from leaf base; 3-distance between bases of 1st and 2nd veins; 4-distance between the extremities of the 1st and 2nd veins; 5-angle between the main and 2nd from the leaf base vein.

All calculations were done using MS Office Excel 2010. A score scale was developed to assess the rate of morphological deviations from the normal leaf from the unpolluted zone (as developed by A.R. Dadayeva) (Table 2). The value of the complex indicator of asymmetry corresponding to conditionally normal status is considered as one score (conditional norm). The value corresponding to the critical status is considered a 5 score (Table 2).

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Score	Value of stability of development	Degree of pollution at the site
I	<0.040	Clean
II	0.040-0.044	Slightly polluted
III	0.045-0.049	Moderately polluted
IV	0.050-0.054	Polluted
V	>0.054	Highly polluted

3. Results and Discussions

As shown in Table 3 and Figure 3, all investigated areas are characterized to have different levels of fluctuating asymmetry on the leaves of an elm tree, which exceeds the conditional norm (<0.004). The highest levels of fluctuating asymmetry were recorded in Muborak Gas Processing Plant (0.060), and Shurtan Gas Processing Plant (0.058), which corresponds to score V on the scale of assessment of environment quality – highly polluted state of the environment. In the Shurtan Gaso-Chemical Complex, the fluctuating asymmetry level is 0.049, which corresponds score of III on the scale of environment assessment (moderately polluted). The better ecological situation was found in the relatively clean zone of Karshi City. The mean level of fluctuating asymmetry is 0.043, corresponding to score II of environment assessment – slightly polluted environment.

As seen from Table 3, the territory of Plants the level of fluctuating asymmetry is higher than in sites located at some distance from the Plant territory. This may be related to the level of SO2 concentration, which is higher in industrial sites as compared to Karshi City (Table 1), particularly in Muborak and Shurtan Gas Processing Plants (Figure 3). Thus, there is a relationship between the level of environmental pollution and the level of fluctuating asymmetry.

Table 3. Level of fluctuating symmetry Ulmus pumila L. in sampled sites

Sampling site	Sample number	Place of sample collection	FA level	Score of state	Mean FA level	Mean score of state
Site 1: Muborak Gas Processing Plant	1	Territory of the plant	0.063	V	0.060	V
	2	Green alley (100 m from the Plant)	0.061	V		
	3	200m from the Plant	0.057	V		
Site 2: Shurtan Gas-Chemical Complex	4	Green alley (100m from the Plant)	0.053	IV	0.049	III
	5	500m from the Complex	0.049	III		
	6	Settlement	0.045	III		
	7	Territory of the plant	0.061	V	0.058	V

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Site 3: Shurtan Gas Processing Plant	8	Green Alley (100m from the Plant	0.054	V		
	9	500m from the Plant	0.059	V		
Control Karshi City	10	The territory of sanatorium	0.038	I	0.043	II
	11	Forestry plot	0.041	II		
	12	Highway	0.046	III		

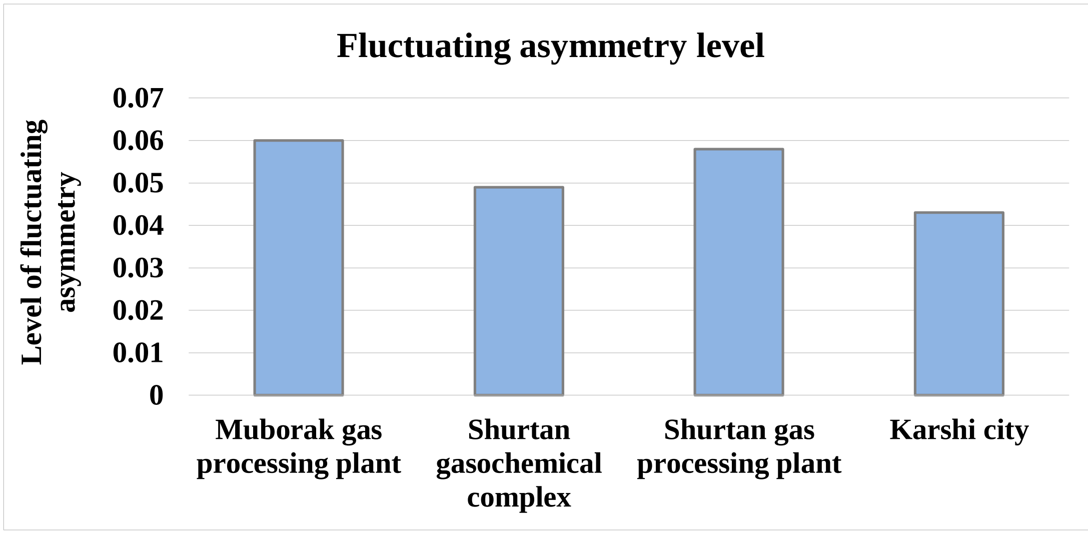

Figure 3. Mean values of fluctuating asymmetry of Ulmus pumila L. in sampled sites

There exists some relationship between the fluctuating asymmetry (FA) values within the territory of the object and the distance from the source of pollution. For example, high FA values on elm tree leaves in Muborak Gas Processing plant and Shurtan Gas Processing plant sites are related to the immediate proximity to the source of pollution. Figure 4 shows the trend of dependence of FA values and the distance of the woodlot from the sources of pollution.

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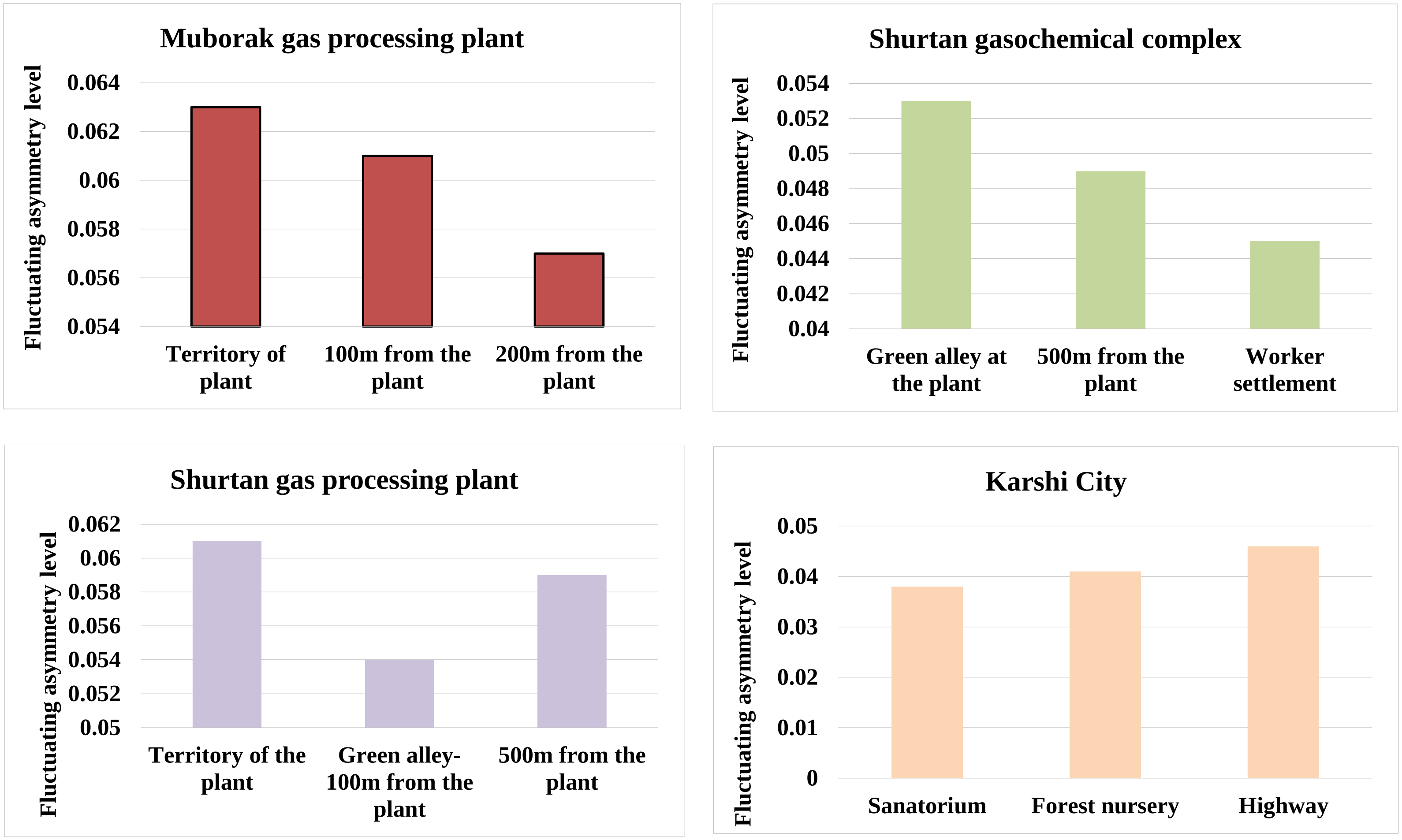

Figure 4: Fluctuating asymmetry value at different distances from the industrial zone

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As seen from Figure 4, in Muborak Gas Processing Plant (industrial territory, woodlot 100m from the industrial area and another woodlot located 200 m from the industrial area) and in Shurtan Gas Processing Plant (industrial territory, green alley at 100m and woodlot at 500m from Plant), there is a progressive change in FA depending on the distance to the industrial area, which is the source of pollution. There was a highly significant correlation of FA value with the distance to the highway (M-38), which shows that the Mubarak Gas Processing Plant site had high values of FA despite the big distance from the sanitary zone, and these FA values are comparable to those in Shurtan Gas Processing Plant and Shurtan Gaso-Chemical Complex. This is explained most probably by the soil and climatic characteristics of the Muborak Gas Processing Plant and the dominant direction of winds. Apart from industrial air pollution, the air pollution from the M-38 highway road is also affecting the state of the trees and the expression of leaf asymmetry on them. This road is in proximity to Muborak Gas Processing Plant and Shurtan Gas Processing Plant. Figure 4 shows the dependence of the FA value on the distance between the woodlot site and the source of pollution. The closer is the woodlot to the industrial site or highway, the higher the value of FA. The correlation between FA value and the distance from the industrial site was highly significant with R2 =90%. Therefore, the FA value of elm tree leaves reflects the quality of the environment, namely, the distance from the sources of industrial or road pollution, and the agro-climatic parameters. The results of our study reveal the increased expression of asymmetry on elm tree leaves with an increase in air pollution. Similar results were reported for the birch tree (Betula pendula L.), Tilia cordata (Erofeeva and Yakimov, 2020), Salix alba (Wuytack et al. 2011) and others (Gavrilin and Runova, 2012; Mabrouk et al. 2020).

5. Conclusions

Considering the quality of the environment near industrial zones in Kashkadarya region using the FA values of elm tree leaves in all studied sites except Karshi city, the FA value is high and exceeds the conditional norm (<0.040), which corresponds to 0.056 – the fifth score according to the scale of environment quality assessment scale and it is characterized as a very polluted state of the environment. The highest values of FA are observed in Muborak Gas Processing Plant, Shurtan Gas Processing Plant and Shurtan Gaso-Chemical Complex, respectively, and the better ecological situation is observed within the sanitary zone of Karshi city. The results of the current study allow us to conclude the relationship between FA values with the distance of recreational zones (here the investigated woodlots) to the sources of pollution such as industrial zones or roads, the higher the FA the higher pollution. Therefore, during the study of environmental quality, it is necessary to consider the complex different factors such as the distance to the source of industrial or road pollution and agro-climatic conditions of the studied sites as well as the duration of the vegetative period.

6. References

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